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An Integrated Development Environment for PMESII Model Authoring, Integration, Validation and Debugging

Presenter: James Melhuish

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BAE Systems, Advanced Information Technologies
75th MORSS, EBO Special Session, June 12-14, 2007

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Agenda

- Background
- CMIST Overview
 - Architecture
 - Concept of Operations
- PMESII IDE
 - Model Representation
 - Model Integration
 - Model Execution
- Commander's IDE
 - Model Authoring
 - Model Debugging
 - Model Visualization
- Experimental Results
- Future Work
- Conclusions

Motivation: Understanding the Battlespace

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"...to *anticipate the evolution of the battlespace* in order to pre-empt, influence, and decisively defeat their adversaries *technological progress is still required* to actualize a *culture of prediction*..."

*USAF SAB, Predictive Battlespace Awareness to Improve Military Effectiveness
July 2002, Maj Gen George B. Harrison, USAF (Retired), Study Chair*

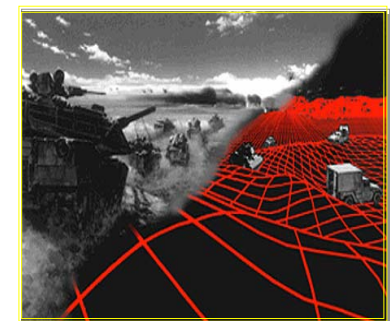
Process	Objective
Joint Integrated Preparation of the Battlespace (JIPB)	Better understanding of the mission space: past, present, future
	Characterize and predict likely future events: intent, reactions, threats
System of Systems Analysis (SoSA)	Analyze the enemy as system of systems.
	Understand key relationships, dependencies, and vulnerabilities.
	Identify leverage points by which to influence capabilities, perceptions, decision making, and behavior.

Visualization



A decision support environment that enables the JFC/JFACC to anticipate and shape the future battlespace

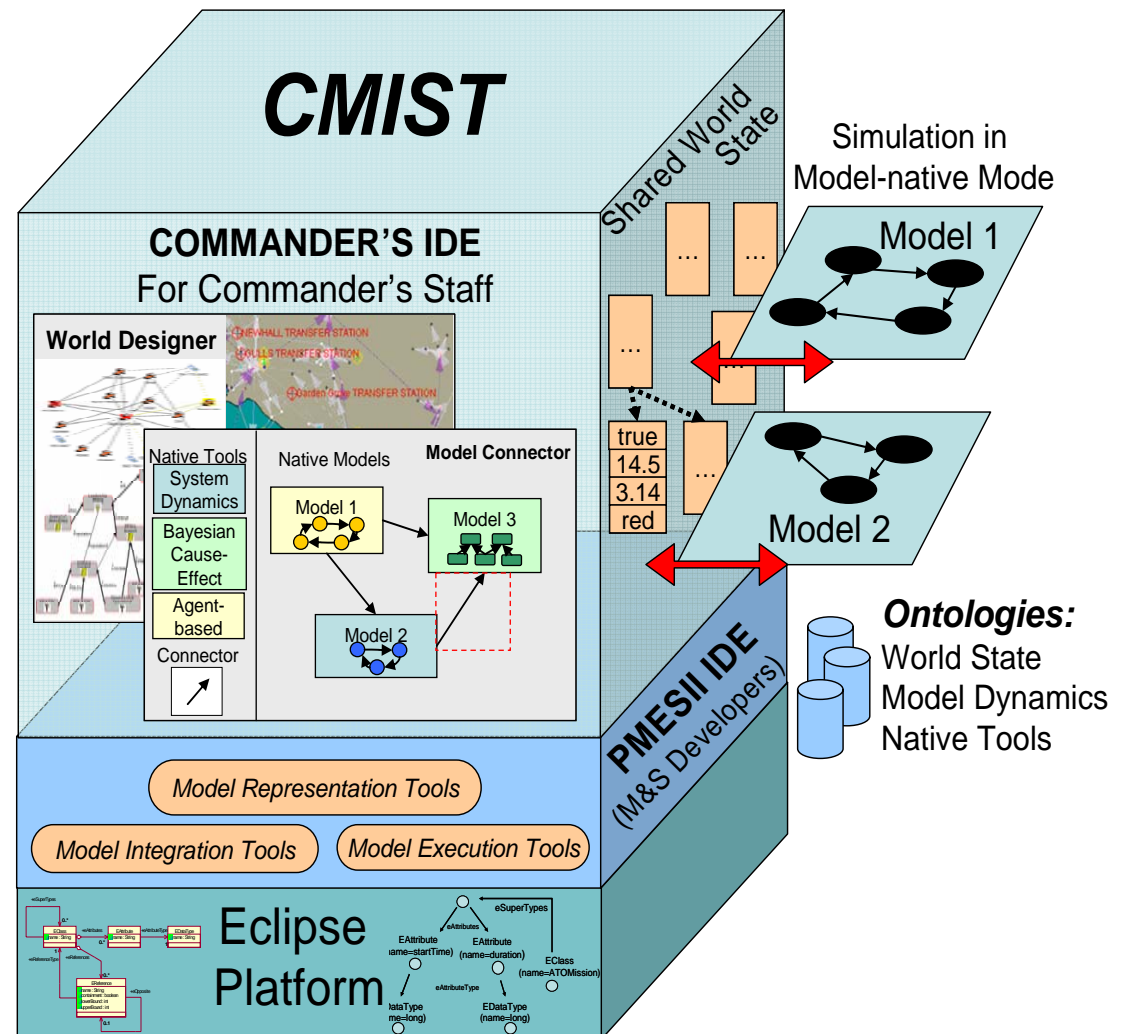
Predictive Battlespace Awareness



Cmdr's Model Integration & Simulation Toolkit (CMIST)

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- **Multi-perspective M&S IDE**
 - Commander-level tools for model authoring, debugging and visualization
 - PMESII M&S developer tools for sim. tool and model integration
- **Built on proven open standards and frameworks**
 - Plug-ins to Eclipse Java IDE
 - Ptolemy II (system dynamics), AFRL CAT (cause-effect), JADE/FIPA (agents)
- **Extensible libraries:**
 - Shared ontologies enable rapid native simulation tool integration
 - Transforms enable cross-model data exchange
 - Interaction patterns synchronize disparate time management within multiple native tools

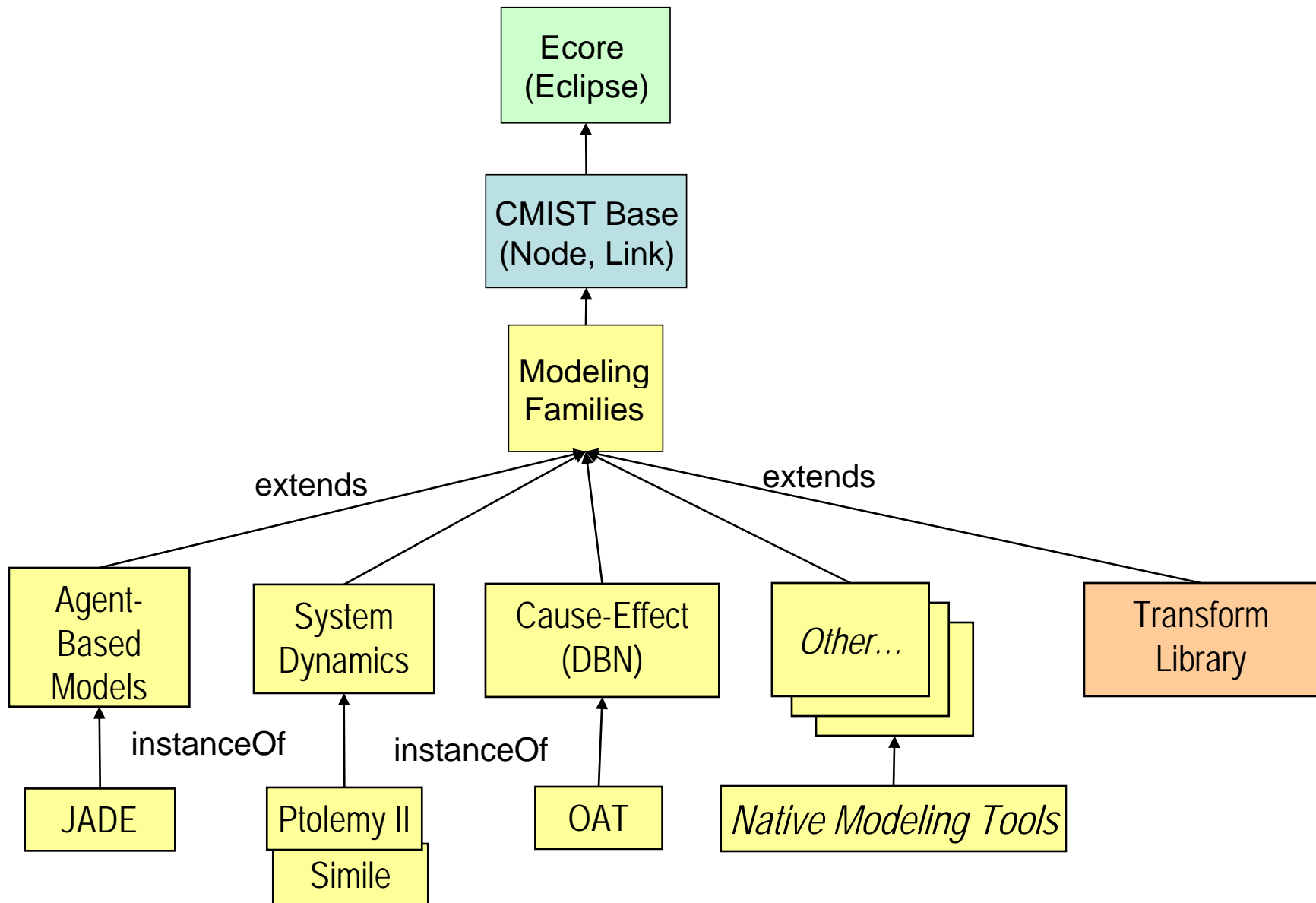


Sponsor:
AFRL/IFS, Commander's Predictive Environment

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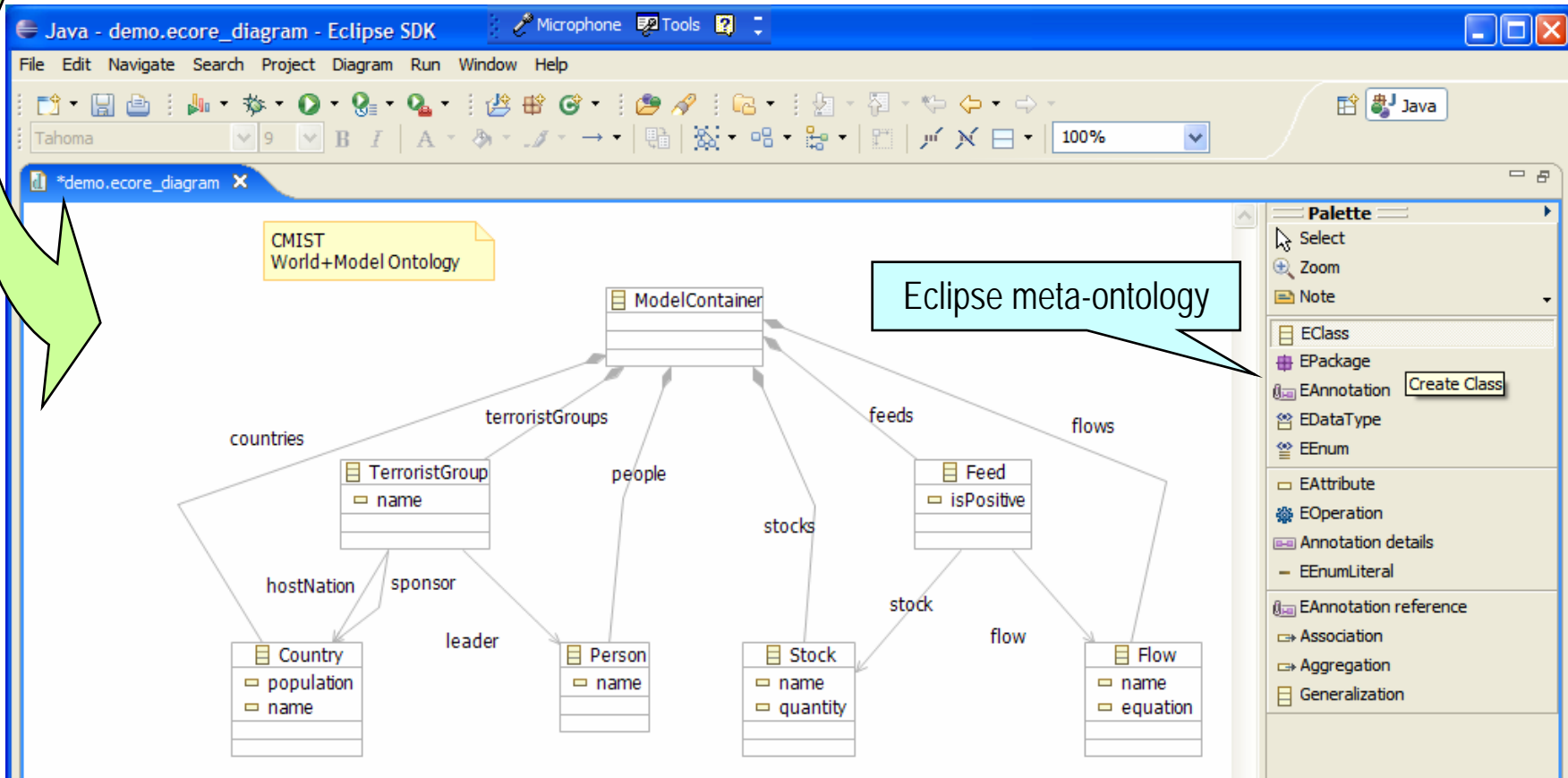
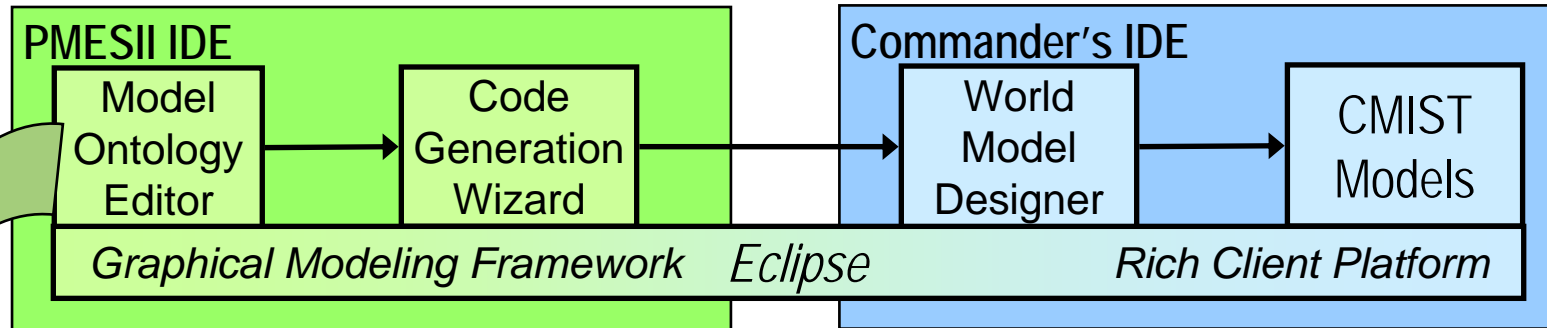
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PMESII IDE Model Representation



CMIST Tool-Making Tools (Editor of environment)

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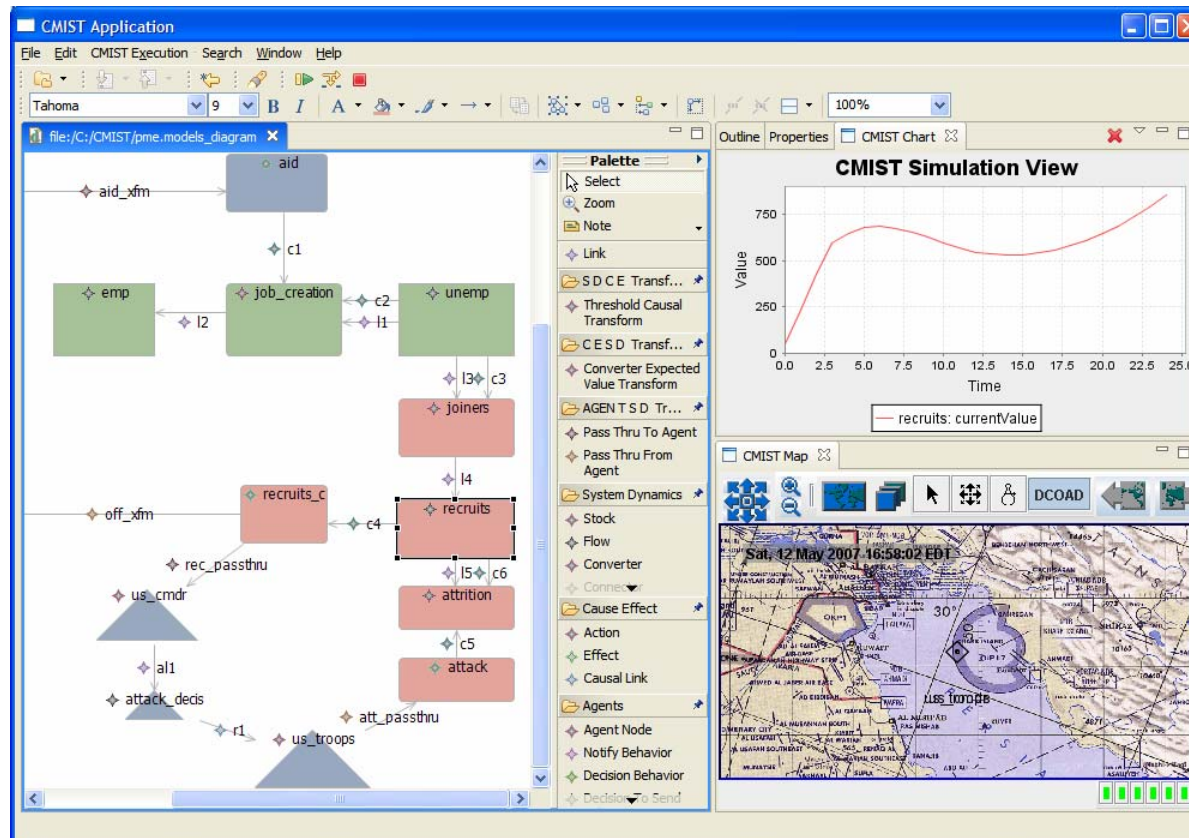
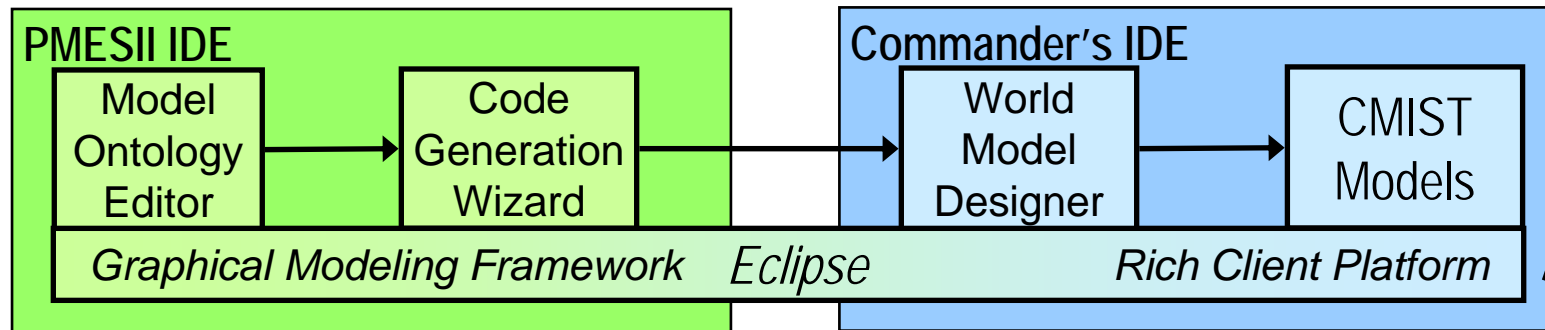


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Modeling tool (Editor of models)

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PMESII IDE Mediation Layer

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- **Alignment Mediators**

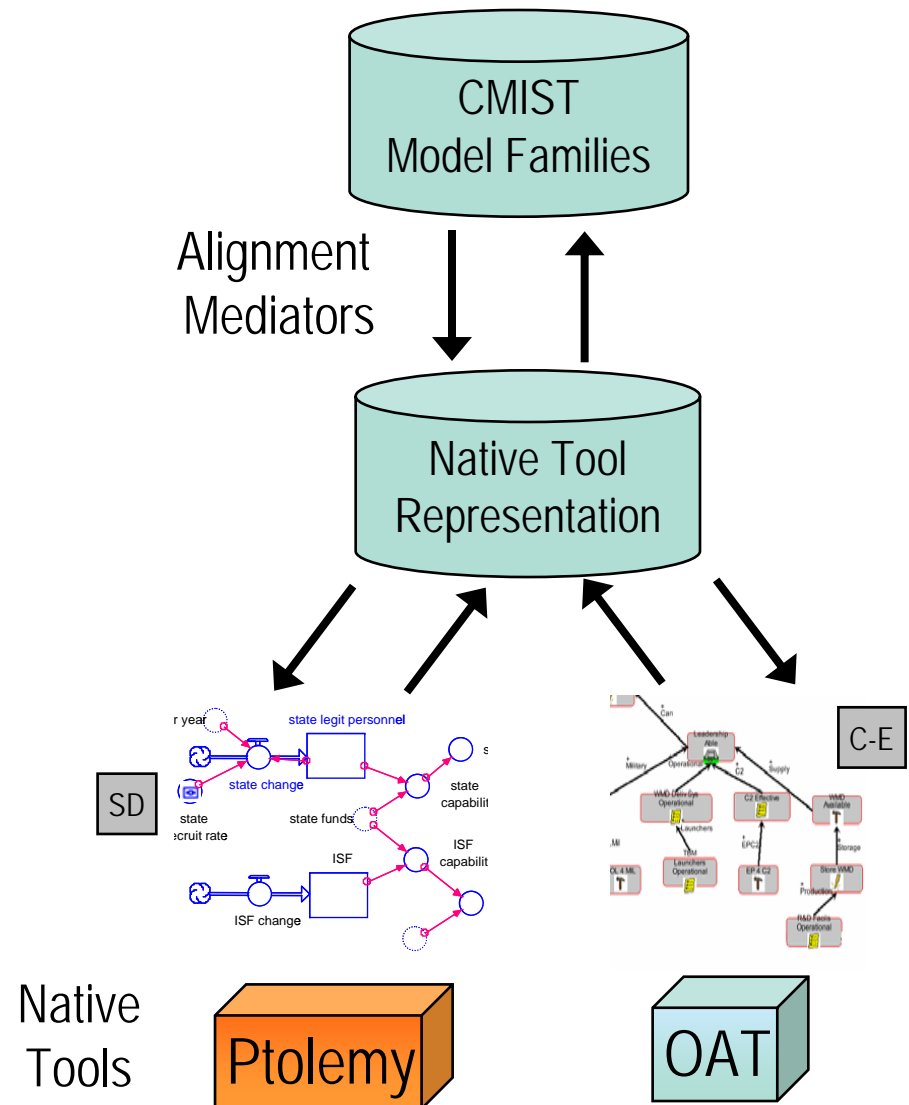
- Map from CMIST Model Ontology to native tool representation
- Automatically timestep the native tool
- Read inputs and write outputs each timestep
- Currently implemented for
 - OAT (Dynamic Bayes Net),
 - Ptolemy (System Dynamics)
 - JADE (Agent-based Modeling)

- **Input mediators**

- Imports a pre-existing native model into the Model Assembly Repository (encapsulation in CMIST)

- **Output mediators**

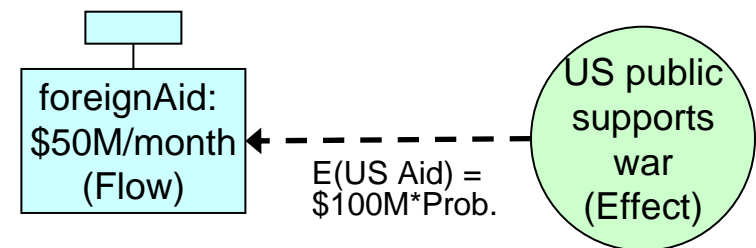
- Exports a CMIST model into a native tool's format



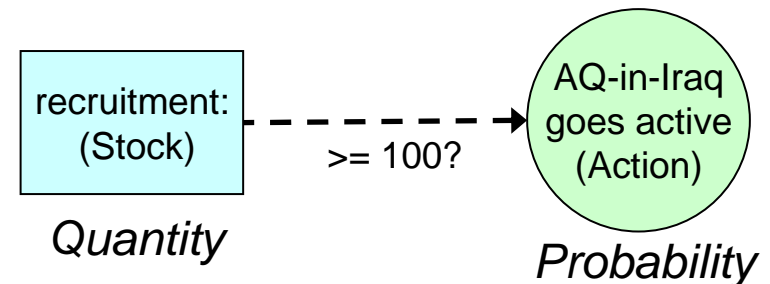
PMESII IDE Transform Library

- Many types of transforms:
 - Map model variables across disparate paradigms (e.g. system dynamics to causal)
 - Map model variables to world state variables
 - Map world state variables to derived variables (e.g. average, sum)
 - 1-to-1, 1-to-many, many-to-1, etc.
- Transform Library
 - Supports transformation reuse across multiple modeling paradigms
 - CMIST will develop canonical transforms for:
 - Probabilistic to deterministic variables
 - Deterministic to probabilistic
 - Agent-state to/from system dynamics
 - Others as needed
 - Library is extensible by end-users

Expected Value Transform

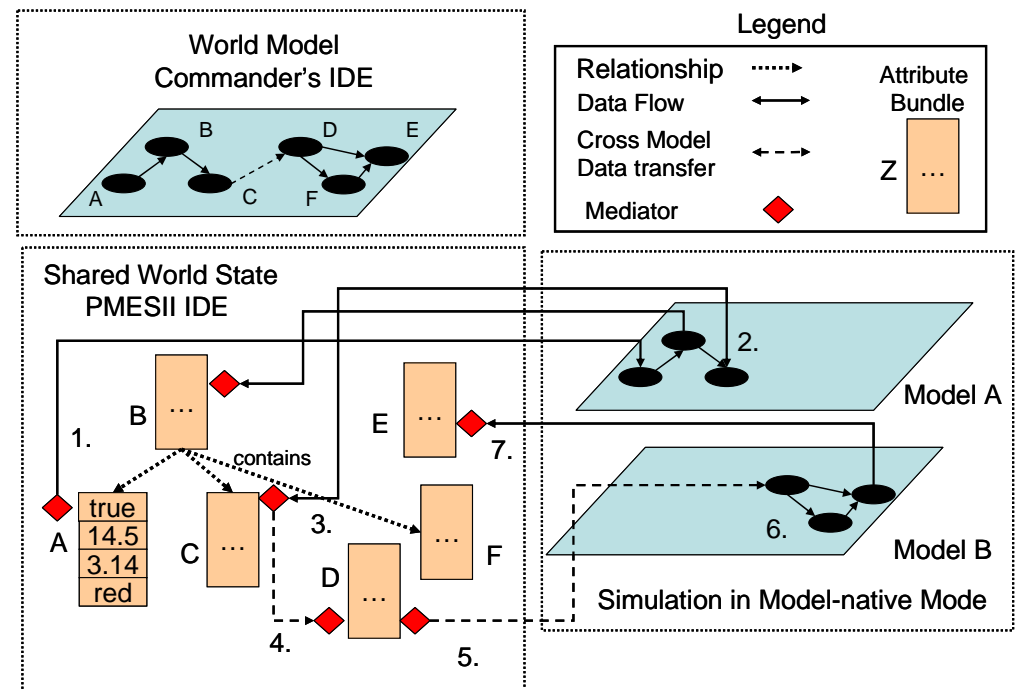


Threshold Transform

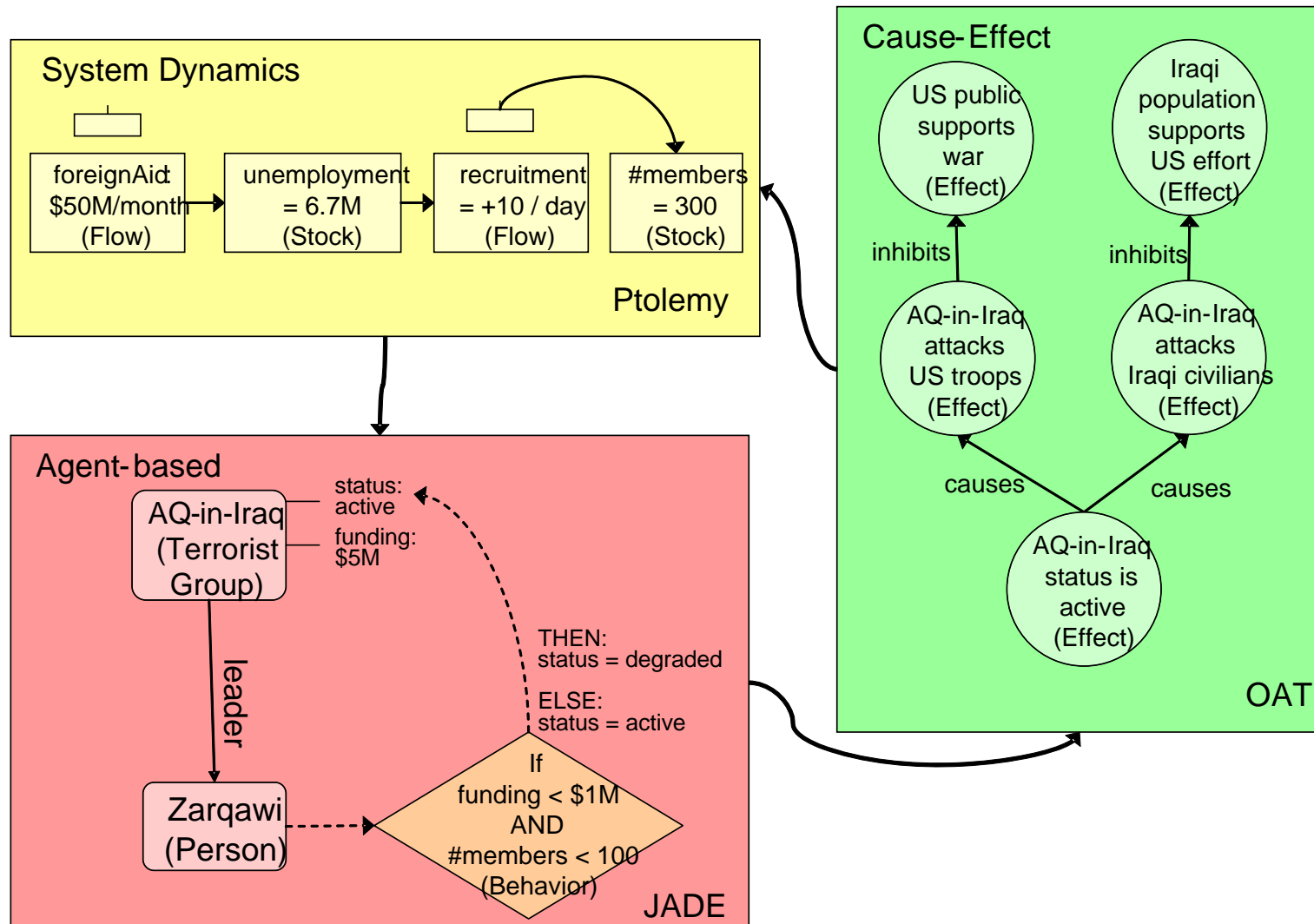


PMESII IDE Model Assembly

- Just prior to running the world model, CMIST compiles a *Model Assembly*
- Assemblies encapsulate:
 - Which world nodes are simulated by which native models & tools
 - How data flows within the *world model*
 - How these data flows are realized in native models via mediators and transforms
 - Structural mappings from CMIST relationships to equivalent native model relationships



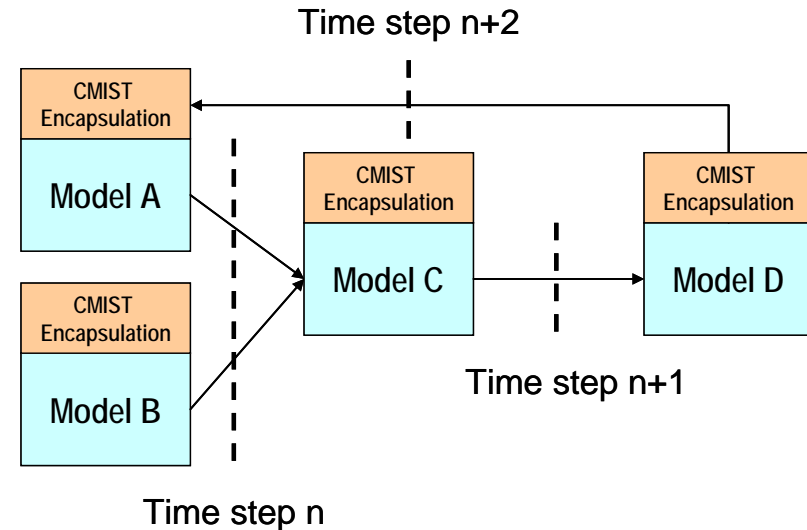
PMESII IDE Model Assembly Example



PMESII IDE Interaction Patterns

- **Parallel Partitions**

- Simple topology with feedback
- All models run synchronously in parallel at constant Δt
- Higher main-loop latency, appropriate for long time-horizons

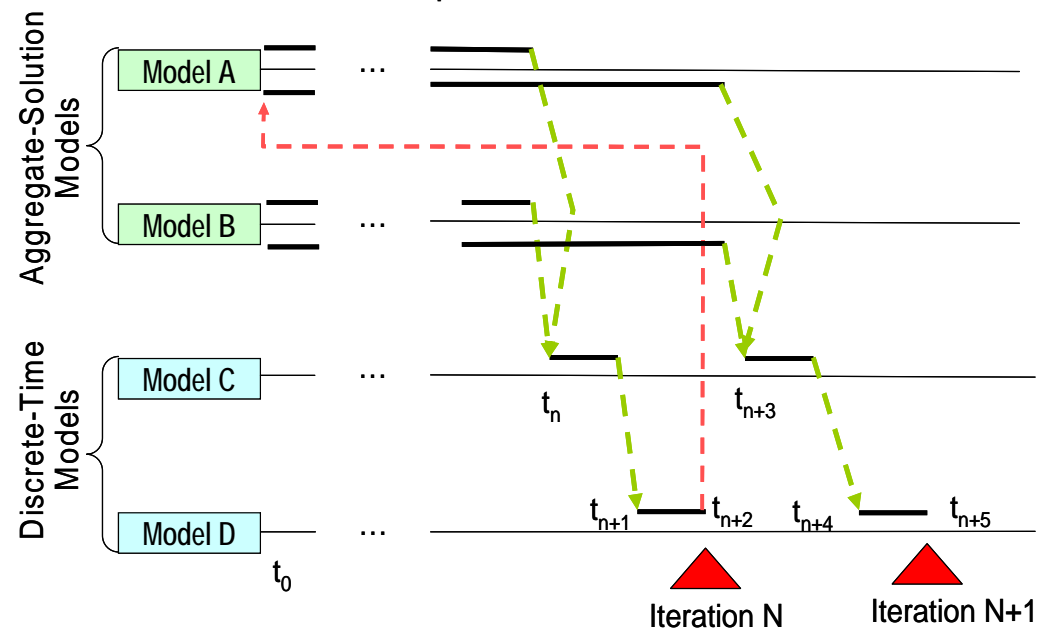


- **Aggregate Partitions**

- Same topology but with A & B as aggregate models
- Model A *reruns* from time 0 to current timestep
- Model B runs just once

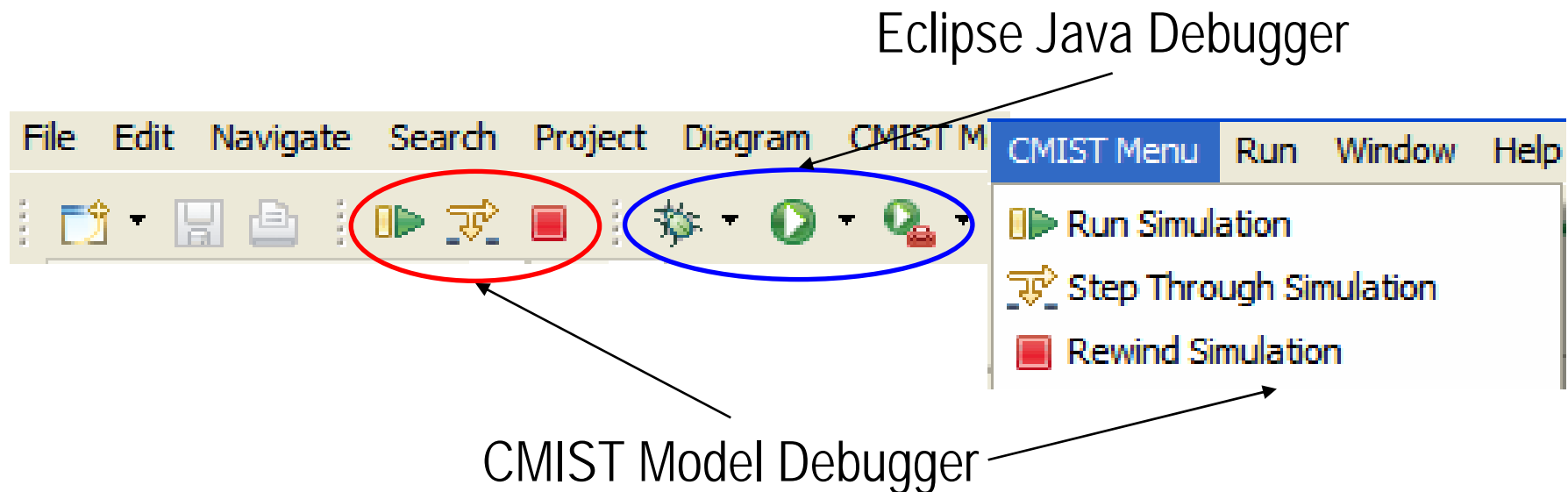
- **Sequential Partitions (TBD)**

- Run A+B, then C, then D
- Less efficient, but reduces data latency over main loop



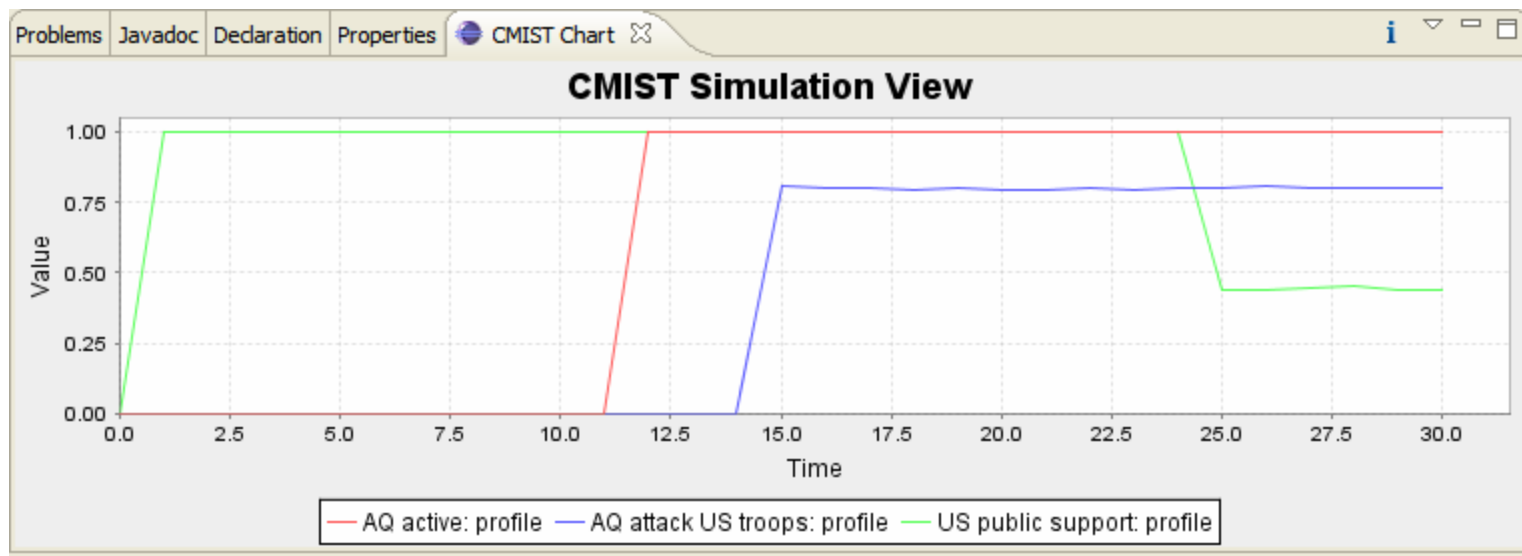
Commander's IDE Model Debugger

- Executes *world simulation* as a multi-resolution model (MRM)
- Analogous to software IDE debugger
- Supported operations:
 - *Run, Pause, Step, Set Breakpoint, Watch Variable*
- Edit configuration information:
 - *Start Time, End Time, Duration, Time Increment*



Commander's IDE World State Inspector

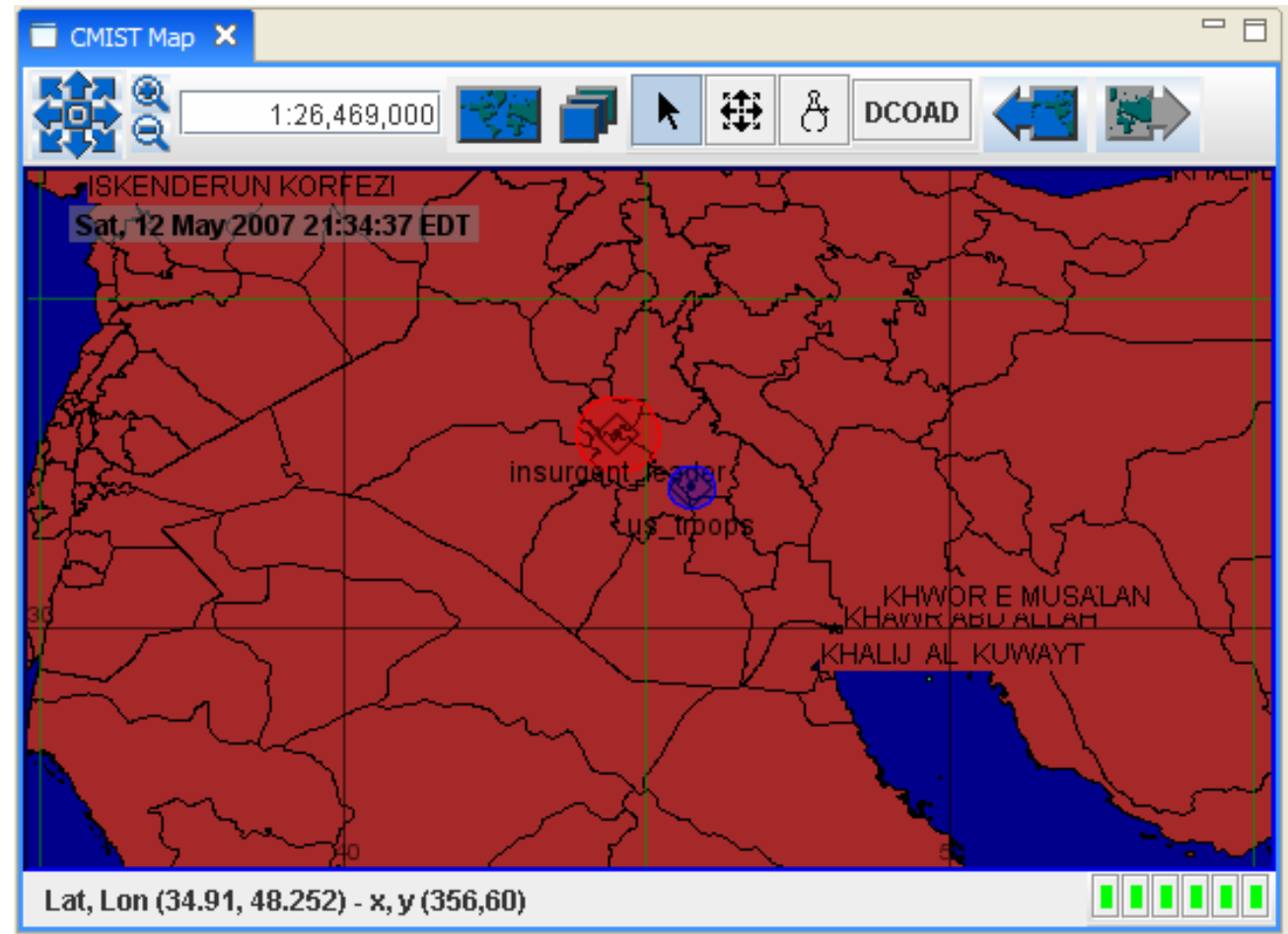
- Time series charts invoked from menu *world model* nodes in World Designer
- Based on JFreeChart



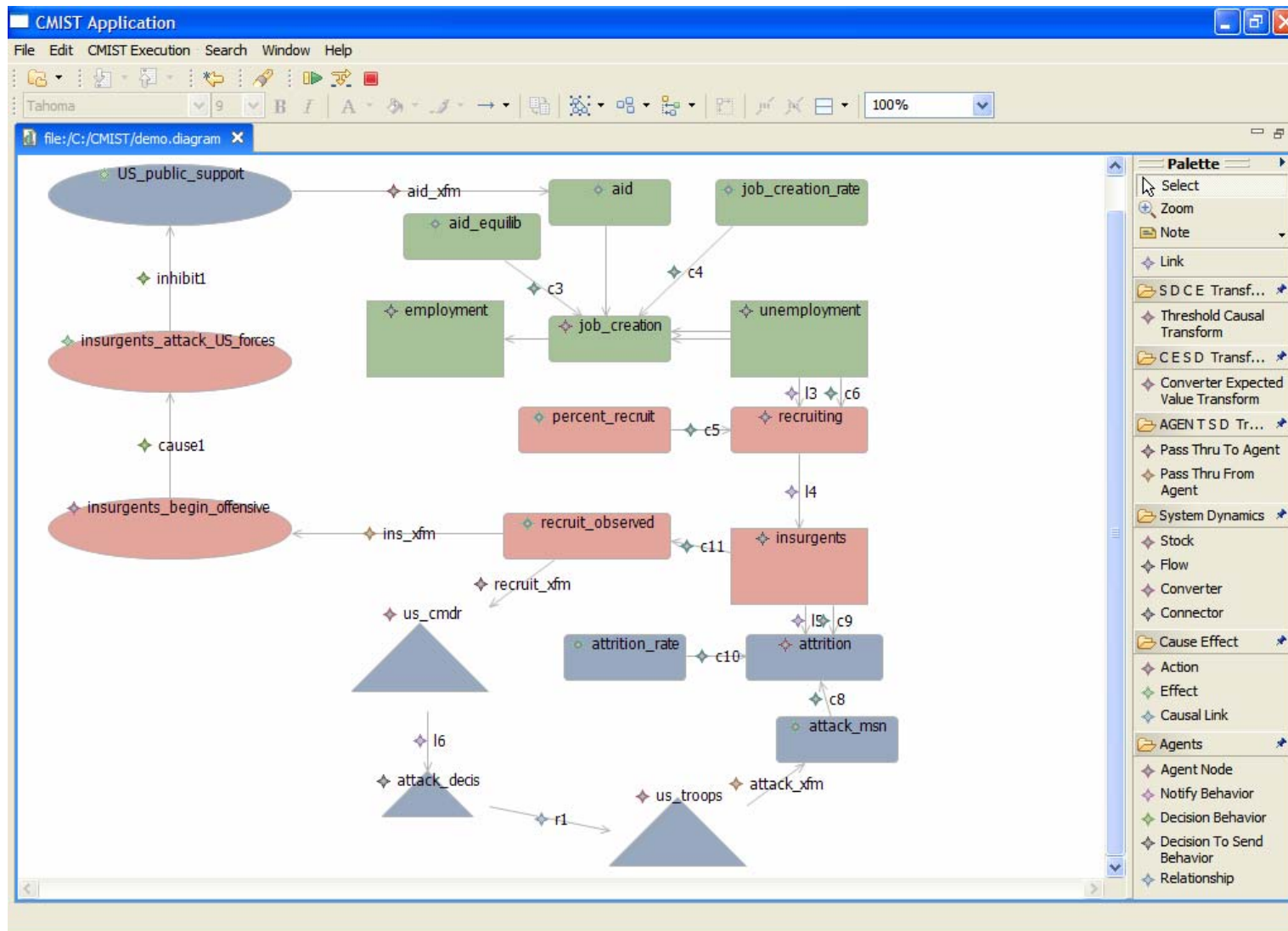
Commander's IDE CMIST Map

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- Leverages AFRL-funded Dynamic Course of Action Decision (DCOAD) tool
- Displays agents at user-specified lat/lon
- Transparent effect-rings grow/shrink in proportion to specified agent property

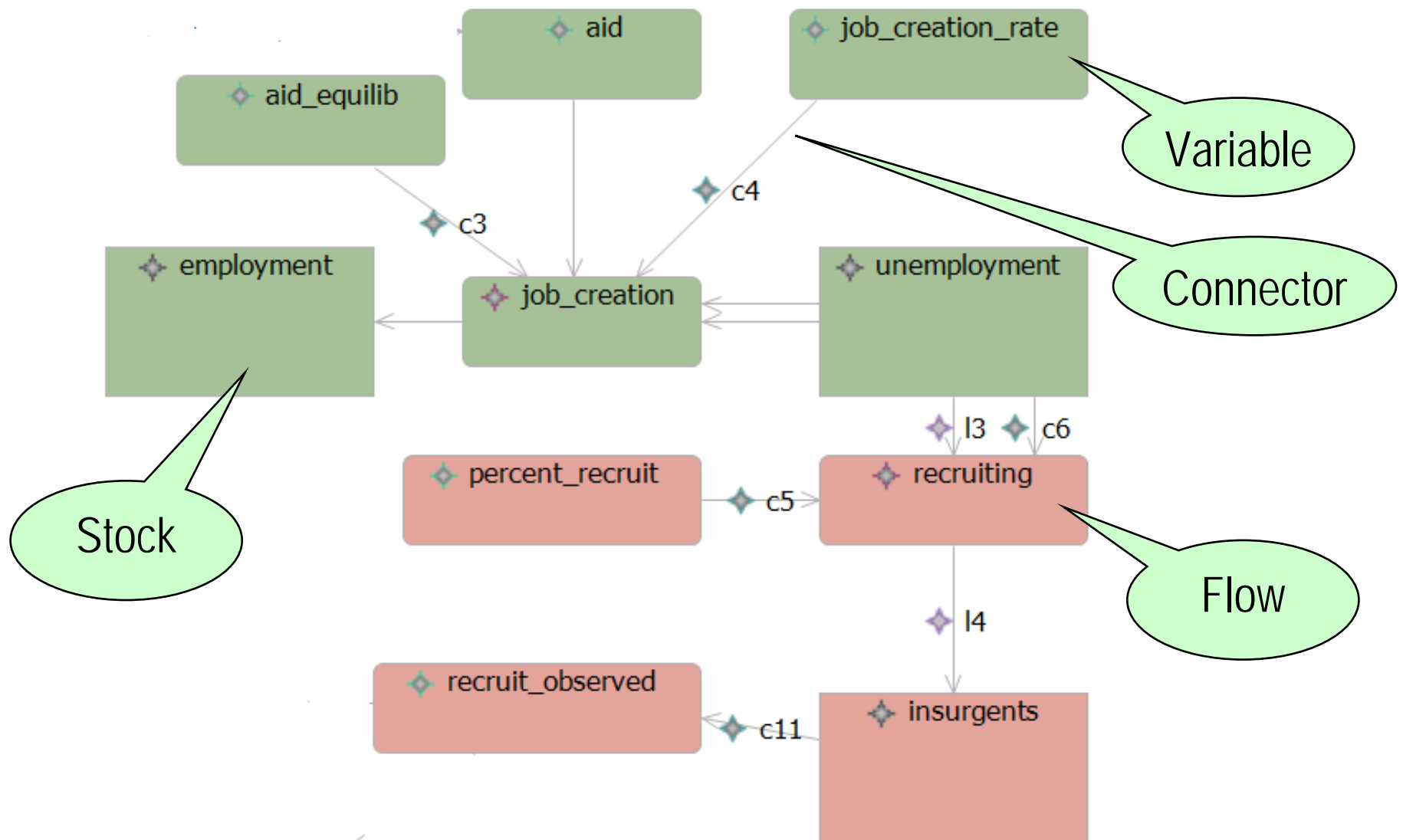


Pol-Mil-Eco Model Scenario

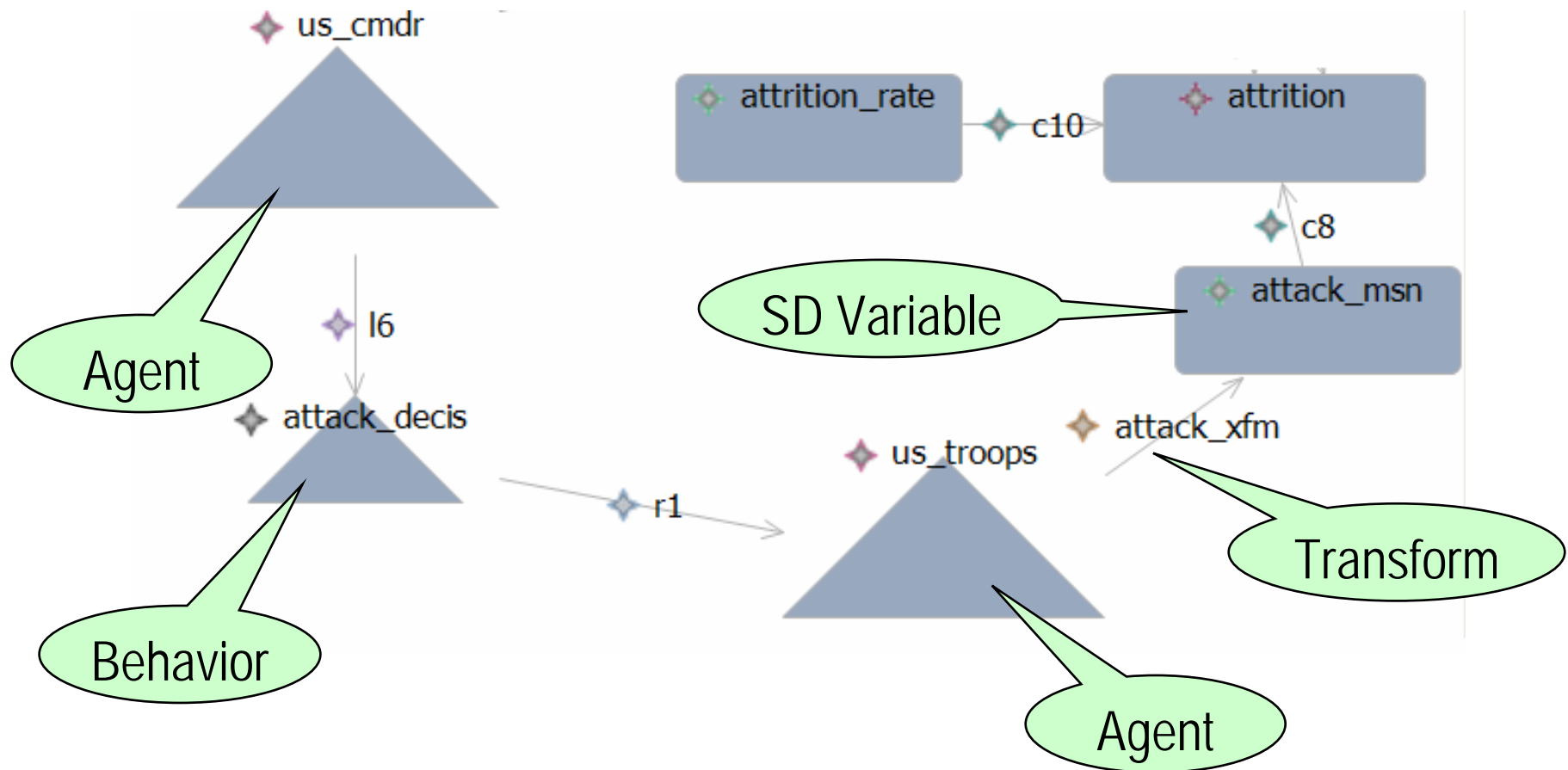


Models presented here are based on notional or open source information

System Dynamics Fragment

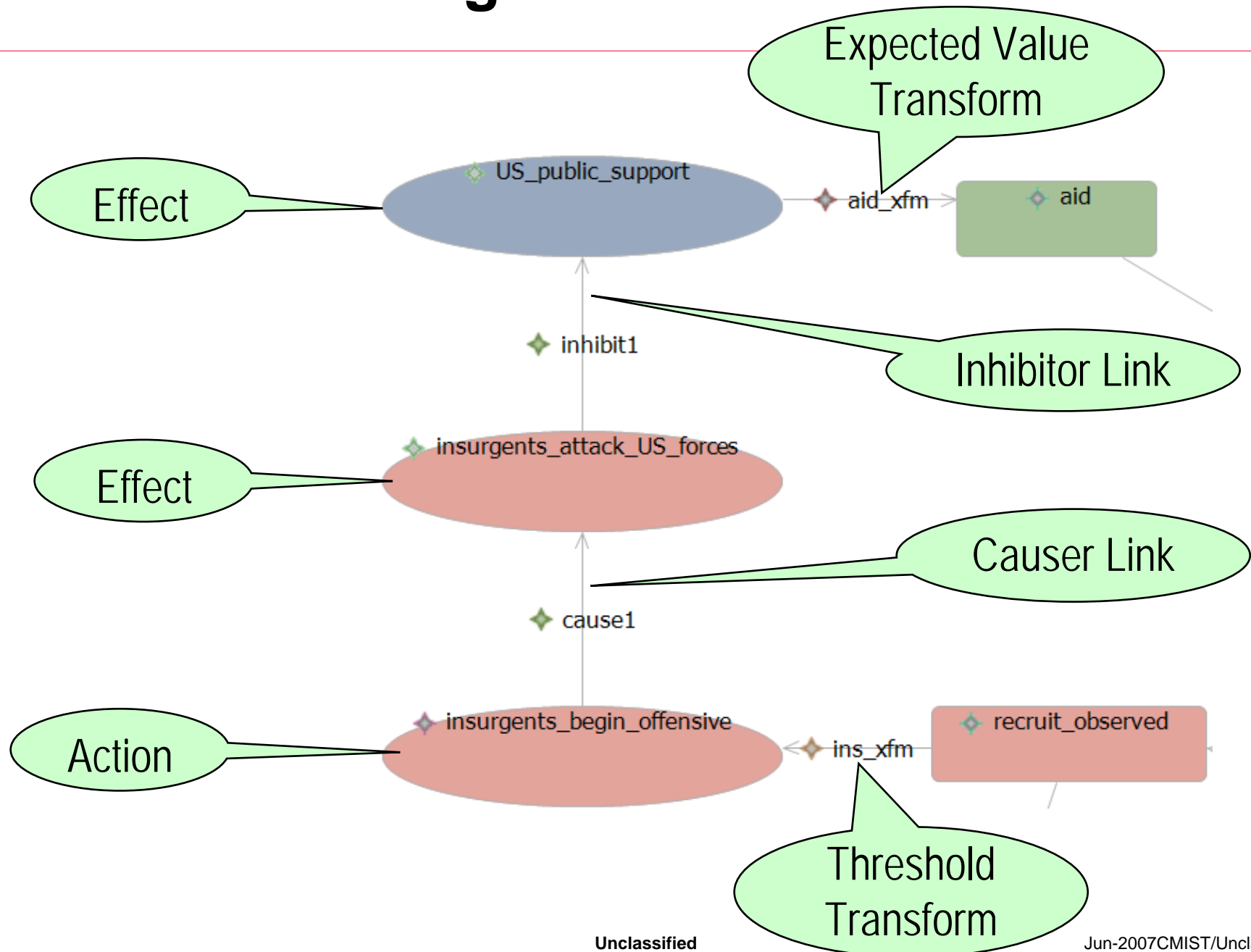


Agent-based Fragment



Cause-Effect Fragment

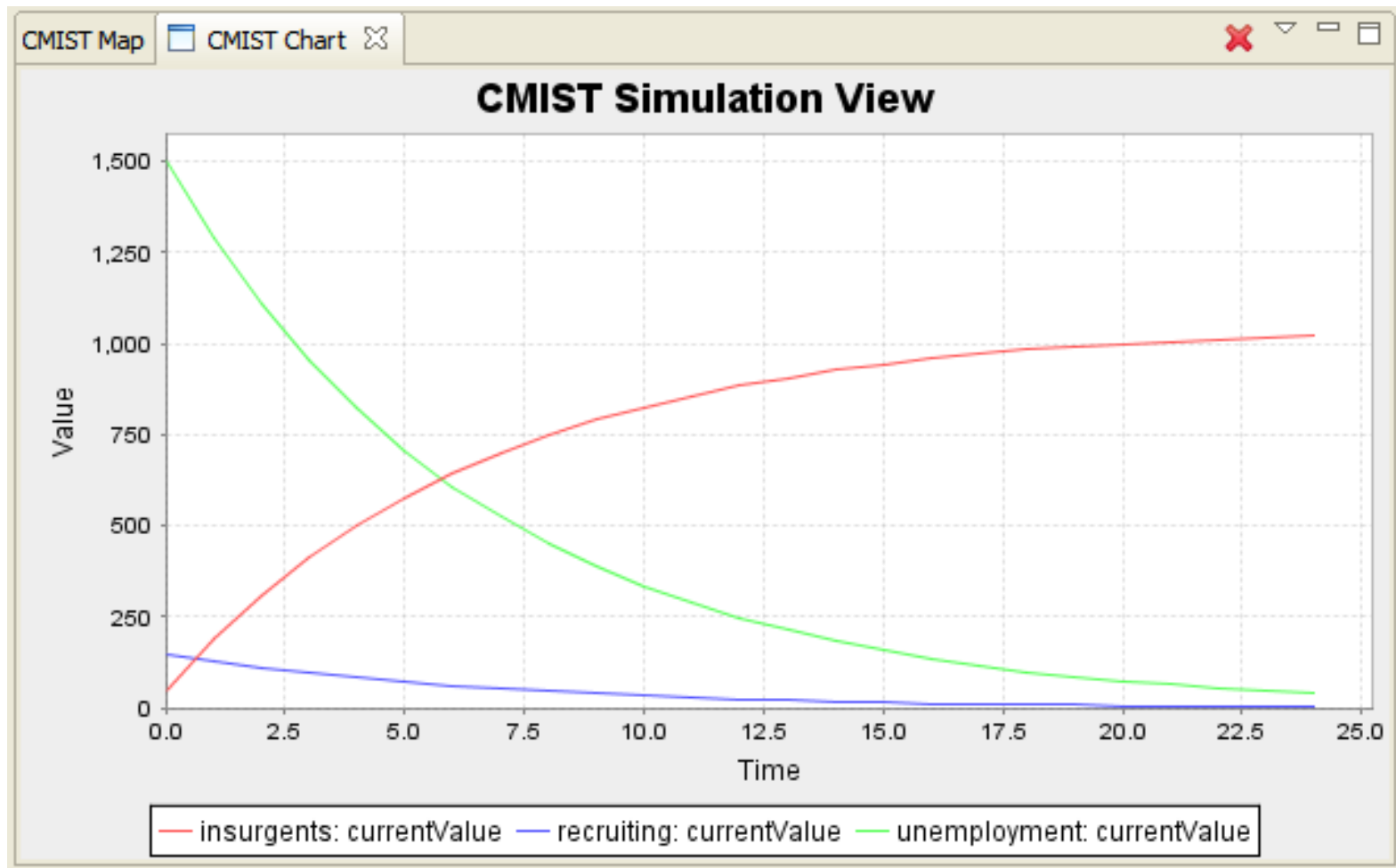
BAE SYSTEMS



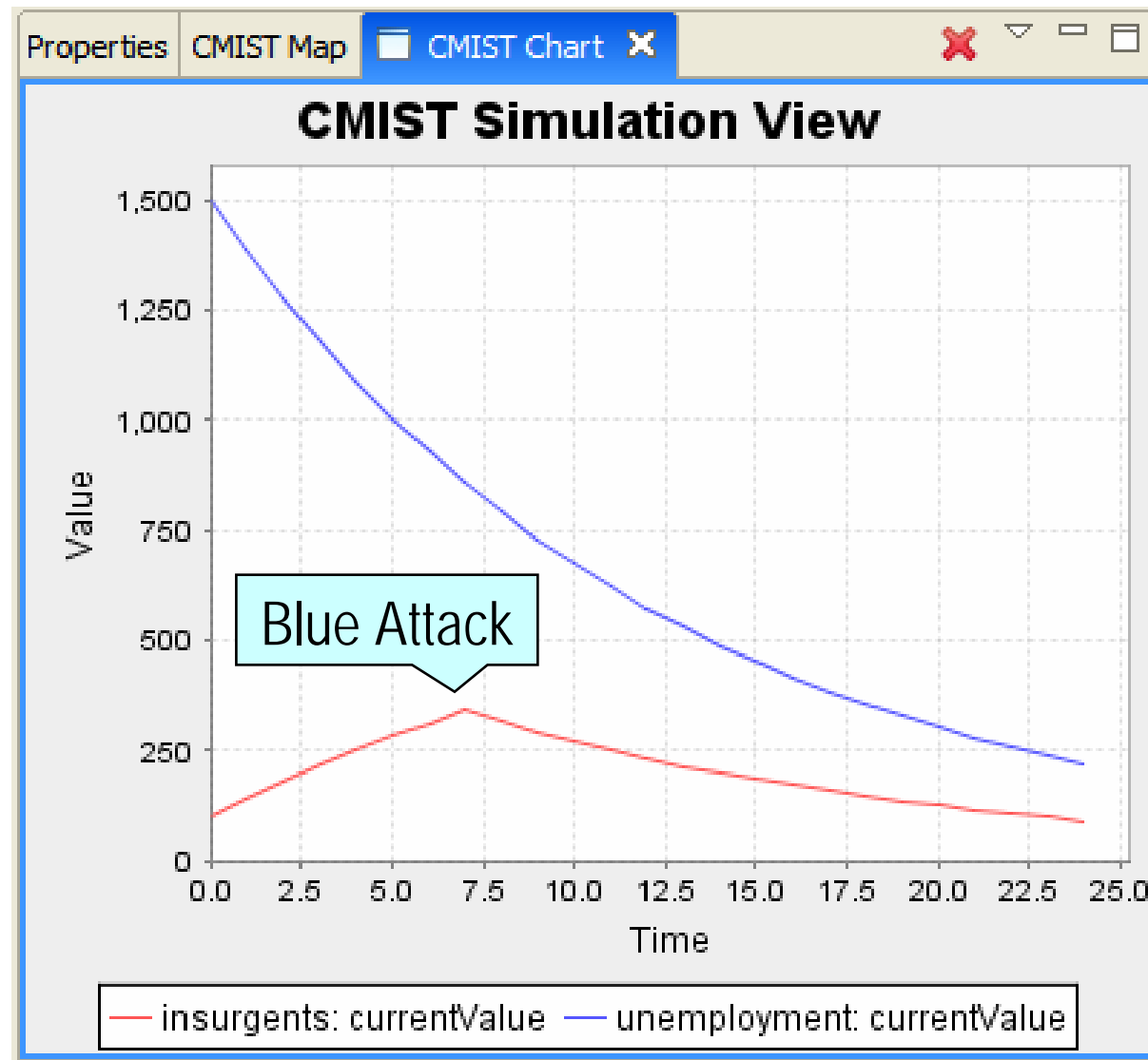
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Results – Baseline red model

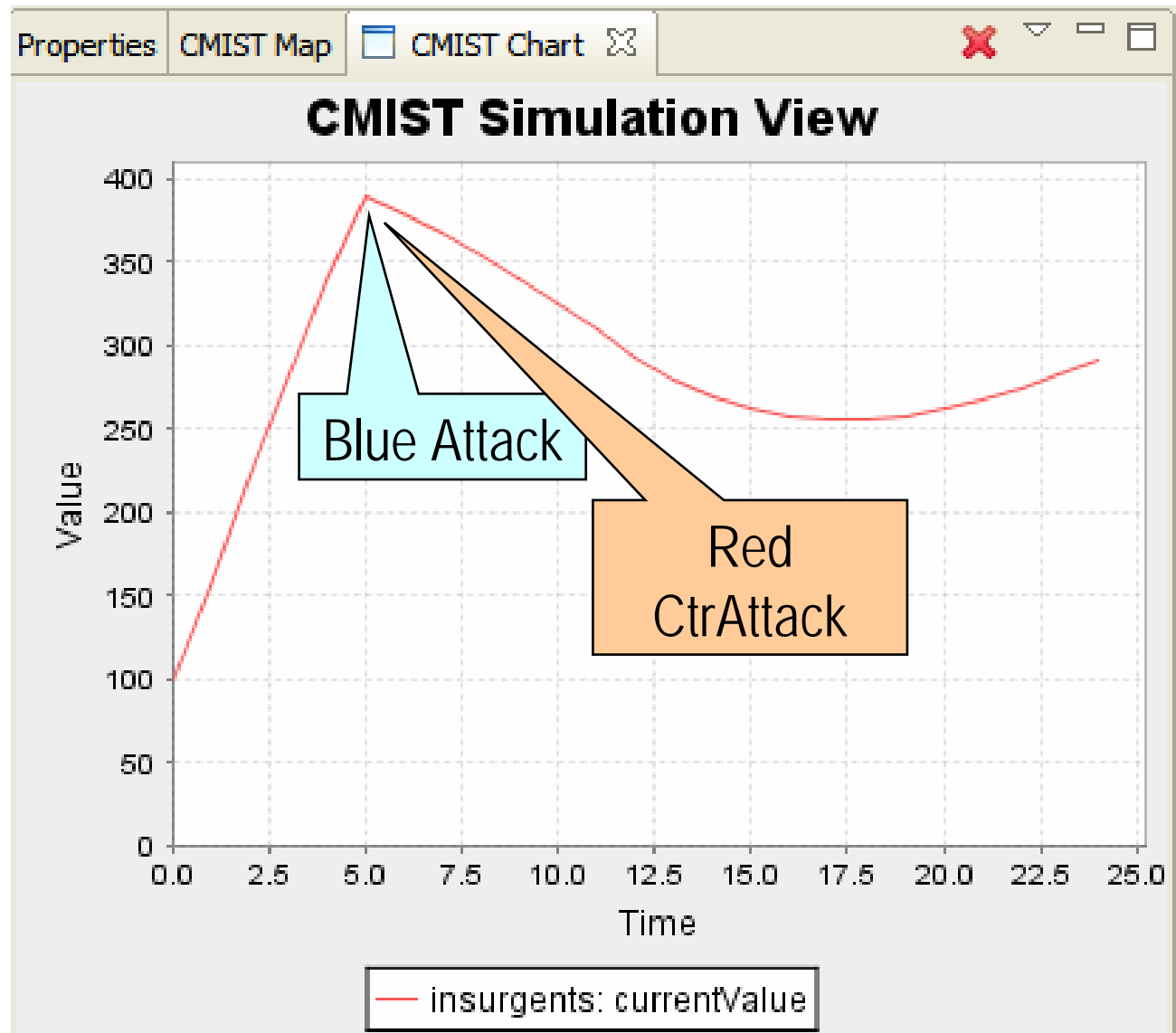


Results – Baseline + Blue Attack



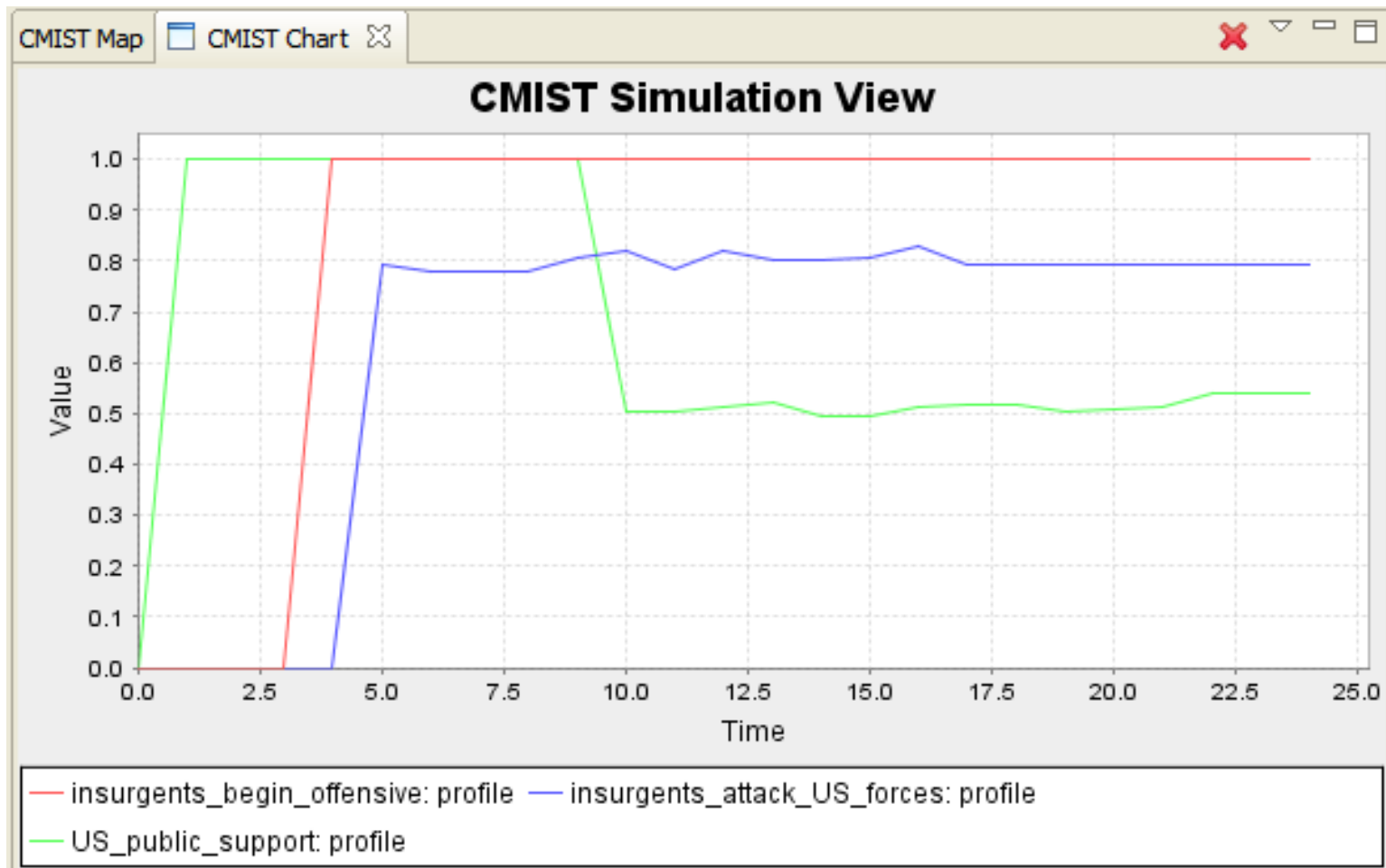
Results

Baseline + Blue Attack + Red CtrAttack



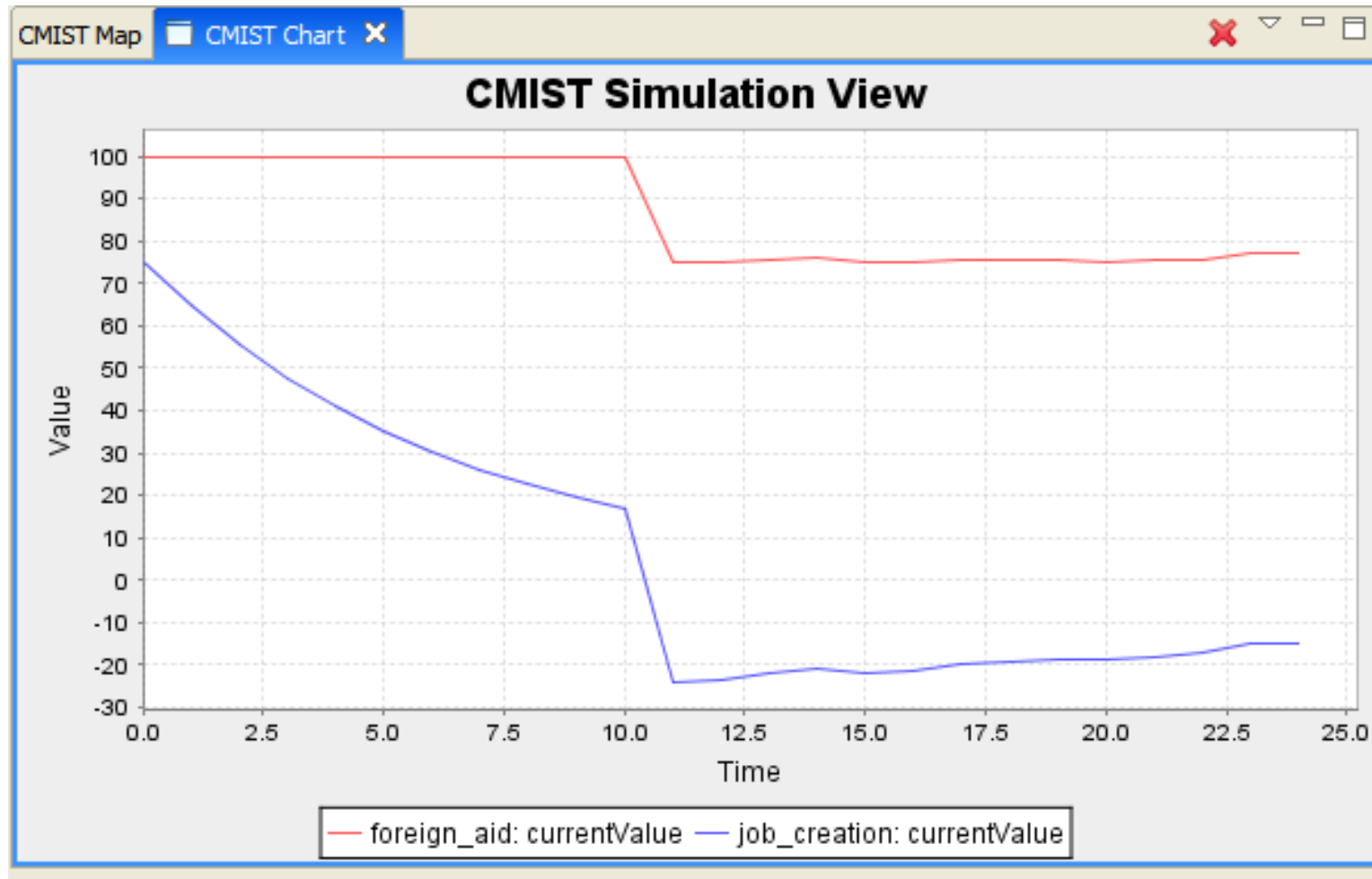
Results

Baseline + Blue Attack + Red CtrAttack



Results

Baseline + Blue Attack + Red CtrAttack



- **CMIST provides a rich platform for PMESII model integration**
 - PMESII IDE for M&S developers to rapidly integrate new native simulation tools
 - Commander's IDE for rapid model authoring, execution, and refinement
 - Powered by Eclipse Modeling Framework
- **Integrated modeling families & tools include:**
 - Cause-effect (AFRL CAT)
 - System Dynamics (Simulistics' SIMILE, U. Berkeley's Ptolemy II)
 - Agent-based modeling (TILab's JADE)
- **Promising initial results on small-scale Pol-Mil-Eco model**
 - Successfully demonstrates CE-SD interactions
 - Combines native tools with discrete vs. aggregate time management
- **Possible future research directions:**
 - Larger-scale modeling for DIME vs. PMESII counter-insurgency operations
 - Blue COA evaluation to support Joint Air Estimate Process

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